# PRERATIO PAUSING: EFFECTS OF AN ALTERNATIVE REINFORCER ON FIXED- AND VARIABLE-RATIO RESPONDING

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Seven rats responding under fixed-ratio or variable-ratio schedules of food reinforcement had continuous access to a drinking tube inserted into the operant chamber. Under different conditions they could drink either tap water or one of two saccharin solutions. In a baseline condition, the drinking bottle was empty. Preratio pausing was observed with both schedules, more so with the fixed-ratio than the variable-ratio schedule, and increasing the concentration of the saccharin solution increased the duration of pausing. Comparisons with baseline performances revealed that the additional pausing was largely, but not entirely, spent drinking. The results support the view that pausing under ratio schedules is a consequence of competition between the scheduled reinforcer and alternative reinforcers that also are available within the experimental environment.

*Key words:* fixed-ratio schedules, variable-ratio schedules, preratio pause, postreinforcement pause, food, water, rats

The distinguishing feature of ratio schedules is that reinforcement depends on response output. In the two main versions of the schedule, the response requirement is either constant, that is, fixed ratio (FR), or the requirement varies from one reinforcer to the next, that is, variable ratio (VR). In both cases, the schedule creates a direct correlation between response rate and reinforcement rate, and the response pattern that maximizes reinforcement is one of sustained, rapid responding. Nevertheless, numerous experiments have shown different FR and VR performances (e.g., Crossman, Bonem, & Phelps, 1987; Mazur, 1983). For VR schedules, the efficient pattern rapidly emerges. By comparison, performances on FR schedules are characterized by a break in responding at the beginning of each new ratio (the so-called *preratio pause*). The consequence of this pause is that reinforcement rates are lower for FR schedules than they are for equivalent VR schedules.

Various accounts of preratio pausing have been discussed over the years, for example, that pausing is controlled by aversive properties of the upcoming response requirement (e.g., Ferster & Skinner, 1957; Mazur, 2002), or that pausing reflects a balance between excitatory and inhibitory processes (e.g., Keller & Schoenfeld, 1950; Leslie, 1996). The present research was guided by an account in terms of relative reinforcement, in other words, by the possibility that preratio pausing is the outcome of a competition between the responses and reinforcers scheduled by the researcher (e.g., lever pressing, food pellets) and alternative reinforcers that may be available within the experimental setting (cf. Pierce & Epling, 1999; Shull, 1979). Alternative reinforcers often mentioned for rats are those involved in such activities as grooming, resting, and exploring. According to this view, whether the organism engages in the scheduled response or an alternative response at a given point in time depends upon the relative reinforcement that is available for the different activities.

The possibility that ratio performances can be influenced by competition from other activities suggests that interruption of the scheduled response will be most likely at times when the momentary strength of the scheduled reinforcer is low. Researchers usually take steps to maintain the strength of the reinforcer by adjusting reinforcer magnitude and deprivation level. Nevertheless, it is difficult to control for some factors that may re-

duce the strength, most notably the inhibitory aftereffects of the prior reinforcer and the delay to the next one. In the case of FR schedules, these factors are most prevalent at the start of the upcoming ratio—the same time that the preratio pause occurs. Once responding begins, however, further pausing should be infrequent because the response–reinforcer correlation differentially reinforces high rates of responding. By comparison, although preratio pausing on VR schedules also may be influenced by reinforcer aftereffects (Priddle-Higson, Lowe, & Harzem, 1976), pausing is discouraged insofar as the upcoming ratio can be small as well as large (Schlinger, Blakely, & Kaczor, 1990).

Whatever the virtues of analyzing preratio pausing in terms of competition from other activities, a serious limitation is the reliance on such responses as grooming, resting, and exploring, responses that are not often recorded or easily observed. Indeed, the responses that occur during the preratio pause and the reinforcers that maintain such activities are largely a matter of conjecture. The account would be strengthened if direct evidence could be provided to substantiate the roles of alternative behavior and their reinforcers.

In the present experiment, rats were given free access to a drinking bottle containing liquid (either water or a saccharin solution) while responding for food under FR and VR schedules. Viewed in the context of choice procedures, the subjects were exposed to a concurrent schedule in which one alternative provided access to food and the other provided access to water. This procedure bears similarities to studies in which FR responding was studied in conjunction with a second schedule of food reinforcement (LaBounty & Reynolds, 1973; Wood, Martinez, & Willis, 1975), with a second schedule of shock avoidance (Catania, Deegan, & Cook, 1966; Wood, Happ, & Adams, 1983), or, especially, with procedures that also allowed the continuous opportunity to drink water (Alferink, Bartness, & Harder, 1980; Burks, 1970; Iversen, 1976). This literature, however, does not provide much information about interactions that influence pausing. The traditional concurrent studies (i.e., those featuring two schedules of food reinforcement) do not feature an alternative reinforcer that is either continuously available or qualitatively different. Although the studies of avoidance and water consumption meet these criteria, they have not provided comprehensive analyses of preratio pausing because the focus has been on the alternative response. An exception is a study reported by Iversen (1976); we will reserve consideration of his procedures and findings for the Discussion.

We addressed two questions about preratio pausing. First, we were concerned with the direction of control that scheduled and alternative reinforcers exert on each other. Do animals engage in alternative activities because the act of pausing provides an opportunity to do so, or, as suggested by an account in terms of competing activities, do animals take time away from the main response in order to engage in alternative behavior? Second, we were concerned with the extent to which the outcome is governed by the magnitude of the alternative reinforcer (in the present case, the concentration of a saccharin solution provided in the drinking bottle). Would increased magnitude improve the ability of alternative reinforcers to compete with the scheduled one? These two questions are linked. If animals engage in alternative activities only when they are already pausing for other reasons, then changes in the magnitude of the alternative reinforcer should not affect pause durations. If animals pause in order to receive alternative reinforcers, however, then pause durations should vary with the magnitude of the alternative reinforcer.

## METHOD

### Subjects

Seven male albino rats (Sprague-Dawley derived) were approximately 1 year old at the start of the experiment. An 8th rat became ill midway through the experiment, and its data are not reported. Four rats (R02, R07, R33, and R35) had previous experience with ratio schedules, and the remaining 3 (R06, R19, and R41) were inexperienced. All were maintained at 80% of the weights of free-feeding control rats and were housed individually with free access to water. Illumination in the vivarium followed a 16:8 hr light/dark cycle; data were collected during the light period at about the same time each day.

## Apparatus

Two single-lever rodent chambers (Grason-Stadler, Model E3125; 29 cm by 24 cm by 19 cm) were enclosed within sound-attenuating ventilated chests. The lever, which required a minimum force of approximately 0.25 N to operate, was centered on the front wall, 9.5 cm above the grid floor. Each response was accompanied by a feedback stimulus (momentary interruption of the background white noise). The food reinforcer (45-mg Noyes pellets) was delivered to a recessed food cup positioned at floor level directly below the lever. A drinking bottle, mounted on the exterior of the chamber door, was positioned so that the stainless steel drinking tube extended through an aperture in the side wall of the chamber, 12.0 cm from the front wall and 3.5 cm above floor level. The tube protruded 1.0 cm into the chamber and was surrounded by a shield cut from Plexiglas tubing (3.5 cm diameter) that was cemented to the inner wall of the chamber. This arrangement reduced, if not eliminated, the possibility of contact with the tube in ways other than licking. In addition, the distance between the spout and the lever (17 cm at the closest point) prevented simultaneous drinking and lever pressing. Contact with the tube closed an electric circuit, allowing licking to be recorded. The chamber was illuminated by a shielded 3-W light mounted 4 cm to the right of the bottle, and extraneous sounds were masked by white noise and the sound of the ventilating fan. The chambers were linked to microcomputers and recording equipment in an adjacent room.

## Procedure

All sessions ended after 51 ratios, and, with occasional exceptions, were conducted daily. When the required number of responses within a ratio was completed, a tone replaced the white noise and a food pellet was delivered 1 s later. In addition, any responding during the tone extended the delay for an additional 1 s. This procedure was designed to discourage response overruns, that is, continuation of responding after the ratio was completed (cf. Baron & Herpolsheimer, 1999). The rats quickly adapted; after a few encounters with the delay, they consistently left the lever and approached the food cup as soon as the tone came on. Following pellet delivery, the tone was turned off, the white noise was restored, and the contingencies of the next ratio were instituted.

The inexperienced rats were magazine trained and lever pressing was shaped. Then all rats were trained with small FR sizes (up to FR 10), at which point there were no apparent differences as a function of experience. Three rats were observed thereafter under FR schedules, and 4 were observed under VR schedules. The ratio sizes were increased in steps of 5 or 10 to levels that maintained characteristic FR and VR response patterns, that is, a significant number of long pauses for the FR schedules and a preponderance of short pauses for the VR schedules. The final ratio sizes were between 35 and 50. Two rats in the FR condition (R06 and R41) were trained at FR 35, and a 3rd (R07) was trained at FR 50. One rat in the VR condition (R19) was trained at VR 40, and the other 3 (R02, R33, and R35) were trained at VR 50. The VR schedules contained 11 ratios: In the case of VR 40, the ratios were 1, 9, 17, 25, 33, 40, 47, 55, 63, 71, and 79; in the case of VR 50, the ratios were 1, 11, 21, 31, 41, 50, 59, 69, 79, 89, and 99. The rats were observed with the terminal schedules for 20 sessions, at which point performances were stable as indicated by day-to-day variations in pause durations and run rates. During this preliminary phase the drinking bottle was absent.

The remainder of the experiment was organized around three conditions presented sequentially: first, a series of sessions in which the drinking bottle contained tap water; second, a series in which the bottle contained 0.1% saccharin solution (by volume); and finally, a series in which the bottle contained 0.5% saccharin solution. All rats were exposed to the same ascending order of concentrations (i.e., water, 0.1% saccharin, 0.5% saccharin); this procedure was chosen to reduce rat-to-rat variation that would result from different orders of exposure (incentive contrast effects). Observations with a given concentration encompassed 32 consecutive sessions, divided into four blocks of eight sessions. Within each block, the first four sessions included an empty drinking bottle, and the second four included a bottle filled with the appropriate solution.

*Drinking measures.* Drinking was recorded in

two ways. First, the bottles were weighed before and after each session. The difference yielded an overall measure of the amount of liquid consumed during the session. Small quantities of liquid were sometimes spilled onto the plastic shield surrounding the drinking tube when the bottle was inserted into or removed from the chamber. These spills were absorbed with a towel, and changes in the weight of the towel were used to adjust the measure of liquid consumed. Second, data were collected on the individual licking responses. Additional measures of time spent drinking were based on the duration of licking bouts. Licking tended to occur in a series of closely spaced responses; a licking bout was defined as ended when 3 s elapsed without contact with the spout.

*Lever-press measures.* Analyses of lever pressing focused on the preratio pause and the run rate. For the FR schedule, the pause was measured as the time between delivery of the previous reinforcer and completion of the fifth response within the next ratio. The procedure of using the fifth response rather than the first incorporated most of the drinking bouts (87%) into the pause, and it discounted instances in which the sustained part of the ratio run was preceded by a few spaced responses (for a similar approach, see Ator, 1980; Capehart, Eckerman, Guilkey, & Shull, 1980). The same procedure was used for the VR schedule except that pauses preceding ratios with a single response were excluded from the analysis. For both schedules, pauses before the first ratio of the session also were not included. The data analyses described below were based on the last four sessions of a condition (FR = 200 data points; VR = 193, on average), with the exception of the empty-bottle condition, in which case the data come from the final four empty sessions in the 0.5% saccharin condition. Run times, used to calculate running rates, were measured from the fifth to the last response within a ratio.

## RESULTS

As a rule, response patterns became increasingly regular with exposure to each condition; by visual inspection, performances appeared to be stable by the end of the 32 sessions with each concentration. Stability also was evaluated by comparing the geomet-
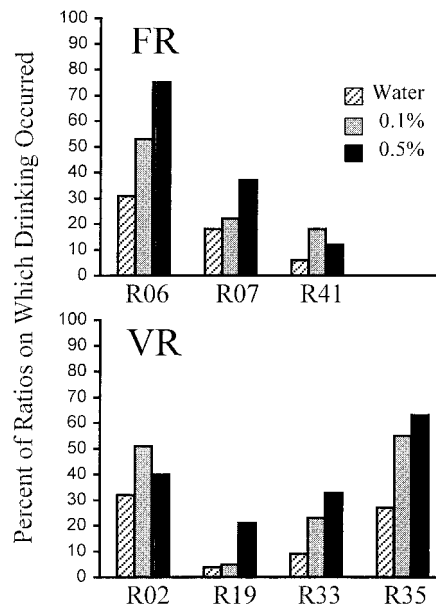


Fig. 1. Percentage of ratios in which drinking occurred for the three experimental conditions. (Water = tap water, 0.1% = 0.1% saccharin solution, 0.5% = 0.5% saccharin solution.)

ric means of the pause distributions during the third and fourth blocks of each condition (the rationale for the geometric mean is given below). Comparisons for both filled- and empty-bottle sessions confirmed that mean differences were relatively small (less than 3 s to 4 s).

### Analyses of Drinking

The rats drank to varying degrees during the course of each session. Drinking did not occur during all ratios, but when drinking did occur it usually commenced early in the preratio pause (within the first 10 s). Figure 1 shows the percentage of ratios during which drinking occurred. All rats drank more frequently under the saccharin conditions than under the tap water condition, and they usually drank the higher concentration more frequently than the lower concentration. Also apparent is the absence of consistent differences between the FR and VR schedules.

Figure 2 summarizes the amount of fluid consumed during the sessions. Paralleling the results for frequency of drinking, the rats drank more saccharin per session than tap water. Noteworthy is that the total amount of tap water consumed was relatively small. On
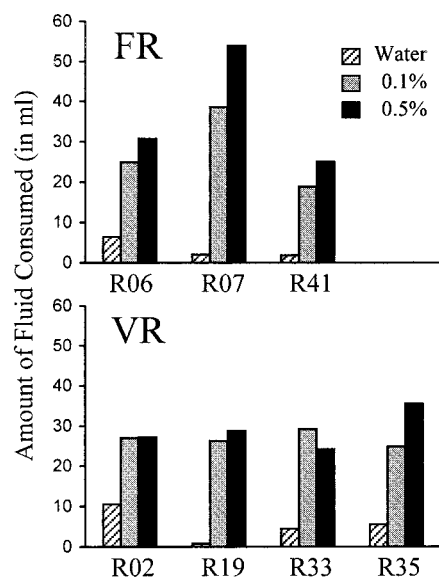
Fig. 2. Amount of fluid consumed during each of the experimental sessions. (Water = tap water, 0.1% = 0.1% saccharin solution, 0.5% = 0.5% saccharin solution.)

average, the amount was 4 to 5 ml, which was no more than about 10% of total daily intake (estimated from consumption on days when experimental sessions were not conducted). By comparison, saccharin consumption was substantial, at least 2.5 times that of water

(R02) and sometimes much greater (R07 and R19).

*Analyses of FR and VR Performances*

The relative frequency distributions in Figures 3 and 4 provide a detailed analysis of preratio pausing. Because of the pronounced positive skew, the results have been graphed on logarithmic axes. The single value displayed within each of the individual panels is the geometric mean of the distribution (i.e., the antilog of the mean of the logarithms). Concerning use of the geometric mean as a measure of central tendency here and in subsequent analyses, there is no consensus about the single measure to be used to represent entire distributions of pauses. Although researchers often use the arithmetic mean, and less frequently the median, the positive skew of preratio-pause distributions makes the arithmetic mean overly dependent on extreme values, and the median fails to capture variations in the extent of the skew. By comparison, the geometric mean provides a measure that is sensitive to extreme values but does not give them undue weight (cf. Shull, 1991).

The frequency distributions in Figure 3 are typical of FR performances (cf. Derenne & Baron, 2001), in that the majority of pauses
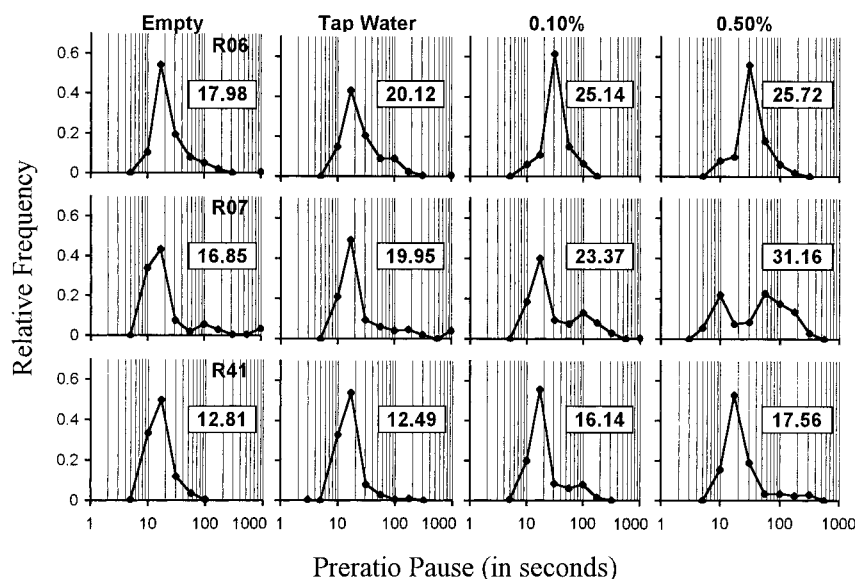


Fig. 3. Relative frequency distributions of pause durations for the 3 rats trained with FR schedules. Vertical grid lines show 0.1 log units. The geometric mean of the distribution is displayed in each of the panels.
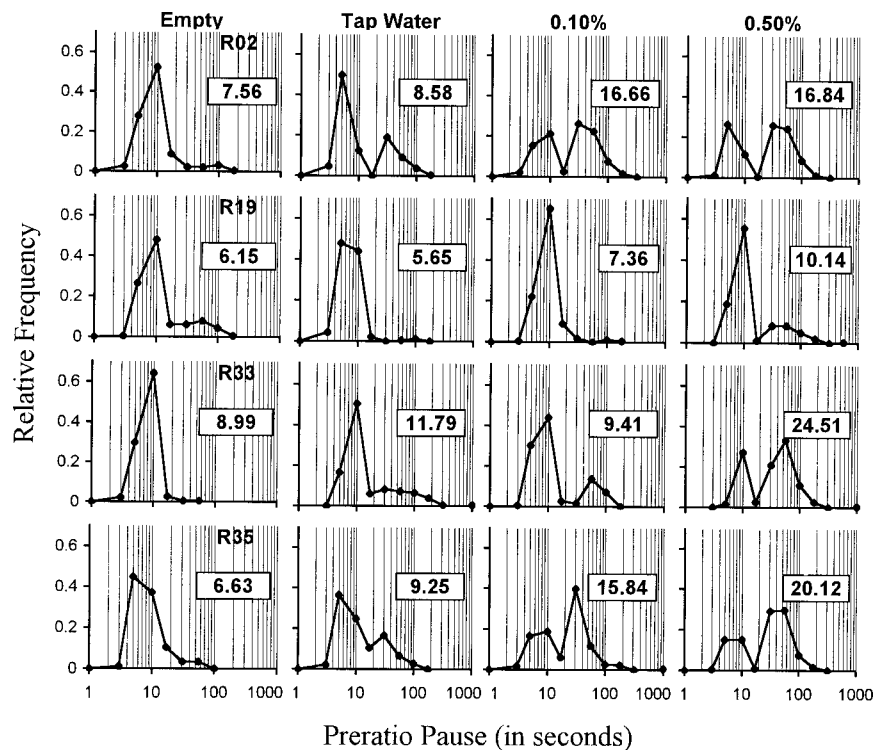
Fig. 4.   Relative frequency distributions of pause durations for the 4 rats trained with VR schedules. Vertical grid lines show 0.1 log units. The geometric mean of the distribution is displayed in each of the panels.

were relatively short, but in many cases a sub-set was considerably longer. In general, the degree of skew became more pronounced as the concentration of saccharin increased, al-though in the case of 1 rat (R06) the most marked change was a shift in the modal point. Figure 4 presents a parallel analysis for the rats trained under the VR schedules. The VR performances resemble FR performances insofar as the distributions also were positive-ly skewed, and the degree of skew also in-creased with the concentration of saccharin. A key difference is that pausing was generally shorter for the VR schedules (the modal points of the distributions are less than 10 s for the VR schedules and more than 10 s for the FR schedules).

To facilitate comparisons of the data in Fig-ures 3 and 4, the geometric means for indi-vidual rats and conditions are summarized in Figure 5 as a bar graph. The bars have been subdivided to reveal the relative contribution of different activities to total pause durations: The upper section of each bar corresponds to time spent drinking during the pause, and the lower section corresponds to time spent in other activities. These results confirm that pausing increased overall as the concentra-tion of saccharin increased, although excep-tions can be seen. To a large extent, the in-crease in pausing resulted from an increase in time spent drinking; however, time spent in other activities during the pause also in-creased as a function of the contents of the bottle.

Two additional analyses were conducted to clarify whether the increased pausing was a direct result of time spent drinking. Figure 6 shows that pausing was consistently longer on ratios in which drinking did occur (the first bar of each pair) than on ratios in which drinking did not occur (the second bar). The second analysis focused on the part of the pause during which the rats were not drink-ing. Figure 7 expresses these durations under the tap water and saccharin conditions rela-tive to time spent pausing under the baseline condition, that is, when the bottle was empty and drinking could not occur. Positive and negative values signify increases and decreas-
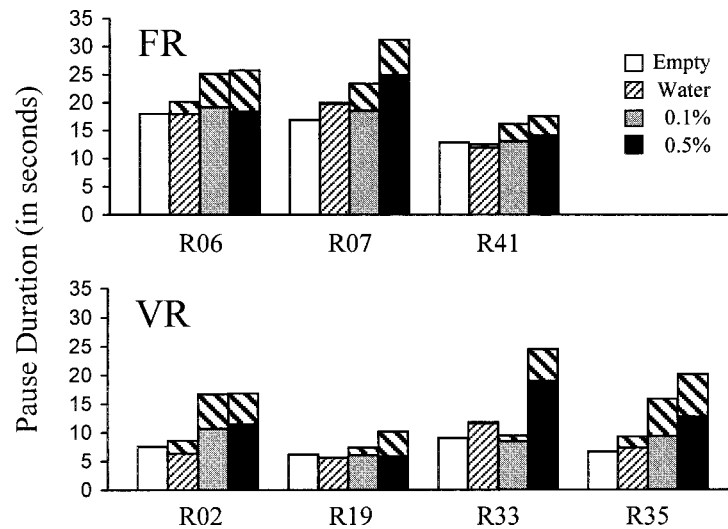
Fig. 5. Pause durations, expressed in terms of the geometric mean. The entire bar length corresponds with the geometric mean of the pause distribution. Within each bar, the upper section reveals the contribution of time spent drinking to total pausing, and the lower section reveals the contribution of other, unmeasured activities. (Empty = empty bottle, Water = tap water, 0.1% = 0.1% saccharin solution, 0.5% = 0.5% saccharin solution.)

es from baseline levels. These data show that pausing exclusive of drinking increased systematically as a function of the contents of the bottle. This outcome is consistent with the other analyses. Although time spent drinking appears to be the primary cause of variations in pausing, time spent engaged in other activities was also affected.

A final analysis examined run rates across the various conditions. The data in Figure 8 show that run rates were not sensitive to variations in the contents of the drinking bottle.
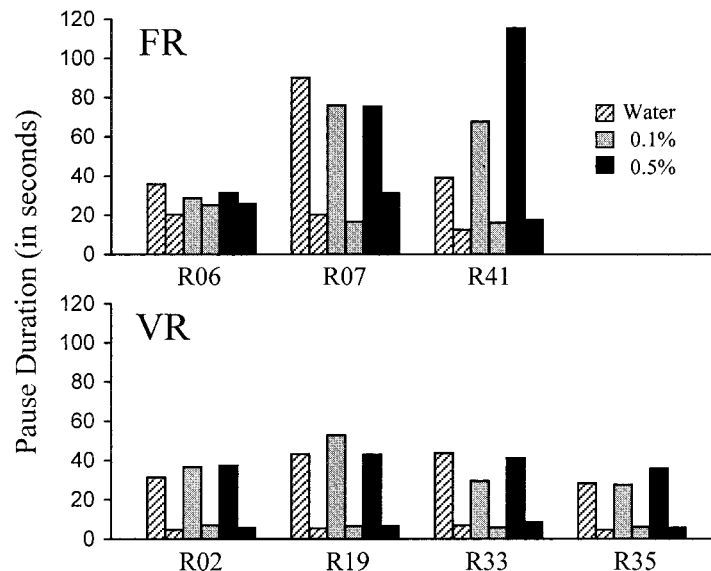


Fig. 6. Pause durations, expressed in terms of the geometric mean. For each pair, the left bar corresponds with pause durations on ratios in which drinking did occur, and the right bar corresponds with pause durations on ratios in which drinking did not occur. (Water = tap water, 0.1% = 0.1% saccharin solution, 0.5% = 0.5% saccharin solution.)
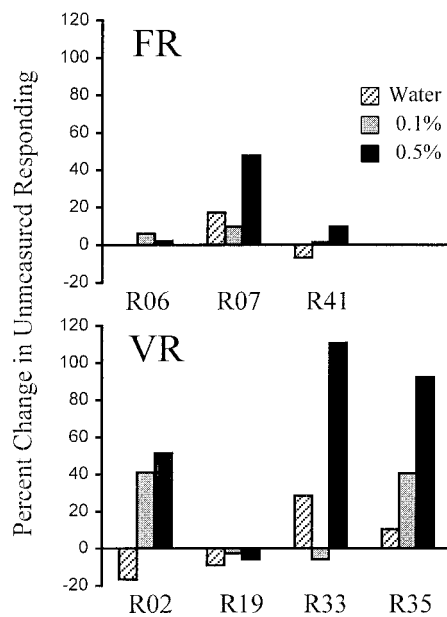
Fig. 7. Percentage change from the baseline condition in the duration of unmeasured activities during the pause for each of the three experimental conditions. (Water = tap water, 0.1% = 0.1% saccharin solution, 0.5% = 0.5% saccharin solution.)
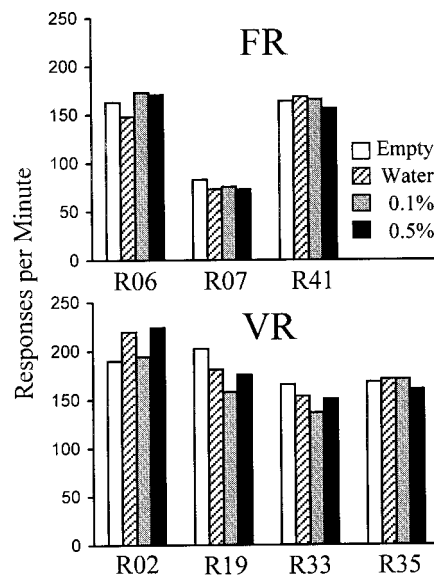


Fig. 8. Average run rates for each of the terminal blocks. (Empty = empty bottle, water = tap water block, 0.1% = 0.1% saccharin solution, 0.5% = 0.5% saccharin solution.)

In addition, run rates did not vary systematically as a function of whether the food schedule was FR or VR.

## DISCUSSION

As noted in the introduction, little is known about what subjects actually do during the preratio pause. The strategy of the present research was to introduce a measurable alternative response—drinking from a continuously available water bottle—into the experimental environment while rats lever pressed for either FR or VR food reinforcement. Interactions of the drinking response with the lever-press response were studied by systematically manipulating the magnitude of the alternative reinforcer, in this case the concentration of a saccharin solution.

The foremost feature of the results was that preratio pausing on both schedules was more prolonged when a second reinforcer was available. In addition, the extent of the increase usually depended on the concentration of saccharin. A closer analysis of the relation between lever pressing and pausing revealed that variations in pausing were large-ly the result of increases in time spent drinking. Thus, the results supported the view that pausing was a direct consequence of the alternative activity of drinking. We found little support for the alternative possibility that the rats simply took the opportunity to drink while pausing for some other reason. Also noteworthy was that the opportunity to drink had only minimal effects on FR or VR run rates. This finding is consistent with the literature on ratio schedules, which has shown that once responding commences, response rates are relatively impervious to the influences of other variables.

Preratio pausing has not been found to be a prominent feature of VR performances. This observation was confirmed by data obtained when the drinking bottle was empty. However, some degree of preratio pausing did occur, despite the occasional small ratios (FR 1), and the same skewed pattern seen for the FR schedules was evident. Variable-ratio performances under the drinking conditions also paralleled FR performances in that the geometric mean of the pauses and the skew of the distribution increased substantially. Given the conventional finding that prolonged pausing is a rarity under VR schedules, it is striking that such pausing under the

saccharin conditions sometimes exceeded that of the FR baseline condition. However, these conclusions should be viewed with caution because comparisons were made on a between- rather than a within-subject basis. At the least, the observations under the VR schedules can be regarded as a systematic replication of procedures with the FR schedules. From this standpoint, the effects of varying the magnitude of the alternative reinforcer were confirmed.

We noted earlier that although the present procedure can be construed as a concurrent schedule of reinforcement, comparisons with the choice literature are difficult because few studies have focused on preratio pausing. The limited data provided by the literature, however, appear to be consistent with the present findings and interpretations. For example, LaBounty and Reynolds (1973) trained pigeons under concurrent FR fixed-interval (FI) food schedules. The cumulative records suggest that the pigeons pecked the ratio key during the early part of the FI and switched to the interval key after the reinforcer was delivered. Thus, preratio pausing tended to occur when the alternative activity was gaining in strength. Perhaps the closest match to the present procedures and findings can be found in Iversen's (1976) experiment in which rats were trained under an FR food schedule with liquid (either water or a sucrose solution) available continuously. His results were similar, in that preratio pausing was more apparent when the liquid contained sucrose. Unfortunately, a procedural complication makes more detailed comparisons problematic. The present analysis envisions two mutually exclusive responses in competition with each other. By comparison, in Iversen's research the lever and the drinking tube were positioned close to one another, thus allowing simultaneous lever pressing and drinking.

Some other aspects of the present results deserve comment. Although pausing consistently increased as a function of the solution, the changes cannot be attributed exclusively to changes in drinking times because some of the changes were due to variations in time spent in other activities (see Figure 7). This outcome points to the complex nature of the act of drinking, which is best regarded as including not only actual time spent drinking but also unspecified preparatory and post-consummatory responses such as the approach to the drinking tube or grooming after drinking is completed. The results also suggested that total pausing on ratios when the rats did drink was about the same regardless of the content of the drinking bottle (see Figure 6; only 1 rat showed an orderly increase as a function of the solution). In other words, the overall pause differences were largely dependent on how frequently the rats drank.

Finally, it is noteworthy that the results did not provide evidence of schedule-induced drinking. Falk (1961, 1966) and others have reported that rats trained on food schedules sometimes drink excessively when water is available in the experimental chamber. By comparison, although the rats in the present experiment consumed substantial amounts of the saccharin solution, there was no indication that they drank excessive amounts of water. The present focus on ratio schedules may be important. Most of the research on schedule-induced drinking has employed fixed-time or FI schedules, and instances of excessive drinking with FR and VR schedules are far less common (however, they have been occasionally reported, e.g., Burks, 1970).

In summary, the present study provided data that are consistent with the view that preratio pausing reflects the influences of competing sources of reinforcement. It would be a mistake, however, to conclude that such an account provides a distinct advantage over alternative views, such as those that focus on the aversive properties of the response requirement or the balance between excitatory and inhibitory processes at the beginning of the ratio. The various interpretations that have been discussed in the literature all appear to be equally capable of dealing with the major findings of research with FR schedules, most notably that ratio performances consist of a pause followed by a ratio run, and that the duration of the pause is affected by ratio size and reinforcer magnitude. Thus, on empirical grounds, there is no obvious basis for choosing among them. Indeed, a case can be made for the view that preratio pausing is multidetermined with all of the various influences playing a role. The special attraction of an account that focuses on interactions with competing activities is that these alternative activities can be

regarded as no more than a second set of operant variables to be studied in terms of the usual operant variables.

## REFERENCES

Alferink, L. A., Bartness, T. J., & Harder, S. R. (1980). Control of the temporal location of polydipsic licking in the rat. *Journal of the Experimental Analysis of Behavior, 33,* 119–129.

Ator, N. A. (1980). Mirror pecking and timeout under a multiple fixed-ratio schedule of food delivery. *Journal of the Experimental Analysis of Behavior, 34,* 319–328.

Baron, A., & Herpolsheimer, L. R. (1999). Averaging effects in the study of fixed-ratio response patterns. *Journal of the Experimental Analysis of Behavior, 71,* 145–153.

Burks, C. D. (1970). Schedule-induced polydipsia: Are response-dependent schedules a limiting condition? *Journal of the Experimental Analysis of Behavior, 13,* 351–358.

Capehart, G. W., Eckerman, D. A., Guilkey, M., & Shull, R. L. (1980). A comparison of ratio and interval reinforcement schedules with comparable interreinforcement times. *Journal of the Experimental Analysis of Behavior, 34,* 61–76.

Catania, A. C., Deegan, J. F., & Cook, L. (1966). Concurrent fixed-ratio and avoidance responding in the squirrel monkey. *Journal of the Experimental Analysis of Behavior, 9,* 227–231.

Crossman, E. K., Bonem, E. J., & Phelps, B. J. (1987). A comparison of response patterns on fixed-, variable-, and random-ratio schedules. *Journal of the Experimental Analysis of Behavior, 48,* 395–406.

Derenne, A., & Baron, A. (2001). Time-out punishment of long pauses on fixed-ratio schedules of reinforcement. *The Psychological Record, 51,* 39–51.

Falk, J. L. (1961). The behavioral regulation of water-electrolyte balance. In M. R. Jones (Ed.), *Nebraska Symposium on Motivation* (pp. 1–33). Lincoln: University of Nebraska Press.

Falk, J. L. (1966). Schedule-induced polydipsia as a function of fixed interval length. *Journal of the Experimental Analysis of Behavior, 9,* 37–39.

Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement.* New York: Appleton-Century-Crofts.

Iversen, I. H. (1976). Interactions between reinforced responses and collateral responses. *The Psychological Record, 26,* 399–413.

Keller, F. S., & Schoenfeld, W. N. (1950). *Principles of psychology: A systematic text in the science of behavior.* New York: Appleton-Century-Crofts.

LaBounty, C. E., & Reynolds, G. S. (1973). An analysis of response and time matching to reinforcement in concurrent ratio-interval schedules. *Journal of the Experimental Analysis of Behavior, 19,* 155–166.

Leslie, J. C. (1996). *Principles of behavioral analysis.* Amsterdam: Harwood Academic.

Mazur, J. E. (1983). Steady-state performances on fixed-, mixed-, and random-ratio schedules. *Journal of the Experimental Analysis of Behavior, 39,* 293–307.

Mazur, J. E. (2002). *Learning and behavior* (5th ed.). Upper Saddle River, NJ: Pearson Education.

Pierce, W. D., & Epling, W. F. (1999). *Behavior analysis and learning* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

Priddle-Higson, P. J., Lowe, C. F., & Harzem, P. (1976). Aftereffects of reinforcement on variable-ratio schedules. *Journal of the Experimental Analysis of Behavior, 25,* 347–354.

Schlinger, H., Blakely, E., & Kaczor, T. (1990). Pausing under variable-ratio schedules: Interaction of reinforcer magnitude, variable-ratio size, and lowest ratio. *Journal of the Experimental Analysis of Behavior, 53,* 133–139.

Shull, R. L. (1979). The post-reinforcement pause: Some implications for the correlational law of effect. In M. D. Zeiler & P. Harzem (Eds.), *Advances in analysis of behaviour: Vol 1. Reinforcement and the organization of behaviour* (pp. 193–221). New York: Wiley.

Shull, R. L. (1991). Mathematical description of operant behavior: An introduction. In I. H. Iversen & K. A. Lattal (Eds.), *Experimental analysis of behavior* (Part 2, pp. 243–282). Amsterdam: Elsevier Science.

Wood, K. A., Happ, A. J., & Adams, C. K. (1983). Ratio responding as a function of concurrent avoidance schedules, yoked shocks, and ratio value. *Journal of the Experimental Analysis of Behavior, 39,* 449–456.

Wood, K. A., Martinez, E. S., & Willis, R. D. (1975). Ratio requirement and reinforcer effects in concurrent fixed-interval fixed-ratio schedules. *Journal of the Experimental Analysis of Behavior, 23,* 87–94.